Along general lines we can apply these same conclusions in the antarctic region; the formation of an area of high pressure over Graham Land, with prevailing winds from south to southeast up to high elevations will be evident proof of the existence of an anticylonic régime in the region of the South Pole. However, I consider this insufficient; the meteorologist ought also to foresee the atmospheric changes that may take place in the succeeding 48 hours.

To this end it would be altogether necessary to install a meteorological station, with its corresponding radio station, on the northwest coast of Graham Land as far as possible to the west and far removed from the aerial base of the expedition. As the displacement of the depressions in the far southern region takes place from west to east this station would be able to telegraph daily the approach of the different atmospheric régimes.

The approach of a depression over Graham Land is announced first of all by the appearance of high cirrus clouds and almost simultaneously by a fall in pressure. If the path of the depression passes to the north or to the south of the place of observation there will be a shifting of the wind. If, as it frequently happens, the observer is north of the center of the LOW, the storm begins with wind from the northeast; as the center of the LOW approaches the wind shifts gradually to north, then to west and afterward to southwest and south in the rear of the depression. In the contrary case, the observer being south of the path of the center of the LOW, the storm will begin with wind from east or southeast which gradually changes to wind of great violence from the south when the center passes at the minimum distance. Innumerable examples can be cited from different polar expeditions.

However, the storm may remain stationary, blowing from northeast or south for several days in the special cases in which there is a rapid succession of secondary depressions; in such cases the hurricane lifts whirls of snow which limit visibility to a few meters and throws the pilot off his course. These "blizzards," as they are called, are the most dangerous storms of the polar region, but their prediction is entirely possible.

The data transmitted by the meteorological station situated on the northwestern coast of Graham Land would be supplemented daily by general meteorological information from southern Australia and New Zealand; these data can be of great usefulness in determining well in advance the approach of the periods of atmospheric stability or instability. The expedition led by Señor Pauly will receive regularly at its base station, Deception Island, meteorological reports from the South Orkneys, Ushuaia, and Australia.

Another very important point is the selection of the most favorable time of the year for carrying out the expedition. It will always be necessary to choose the months of greatest atmospheric stability, when fogs are rare and tempests are infrequent. The statistical data indicate that the most favorable months are those of the summer, and not of the spring as is the case at the North Pole. In the former months the frequency of fog is only 6 per cent and the mean velocity of the wind varies between 5 and 20 km. (3.1 and 12.4 miles) per hour.

CONCLUSION

In this paper we have made a general summary of the meteorological conditions in the antarctic region and have discussed meteorological preparations for aerial expeditions to the South Pole. Many details of organizations are omitted; only the general lines are laid down.

Simultaneous observations made in different regions of the antarctic continent have demonstrated that the variations in atmospheric pressure have successively the same sign over Ross Sea, Antarctic America, and Emperor William II Land. When the pressure is high in the antarctic region it is low in the regions more or less in the vicinity of 40° south latitude, and vice versa.

This antarctic region constitutes one of the greatest centers of action on the globe. The polar observations do not merely have unquestioned theoretical interest, but from a practical standpoint they are of exceedingly great importance in weather forecasting in the temperate regions of the Southern Hemisphere, South America especially.

For this reason the expeditions of Pauly and Byrd assume very great importance in the progress of the meteorological world. The *Observatorio del Salto* takes the greatest pleasure in contributing this grain of sand to the realization of this great scientific expedition.—*Translated from the Spanish by W. W. Reed.*

THE SOURCE OF THE WATER VAPOR OF THE ATMOSPHERE: A CRITICISM

ALFRED J. HENRY

It is well known that water vapor is continually passing into the atmosphere from the surface of the seas and lands at practically all temperatures and pressures and is as continually being withdrawn in the form of rain, snow, hail, sleet, and dew. In many respects the circulation of water vapor into and out of the atmosphere is, if not the most important, one of the most far-reaching importance in its effects both from a physical and an economic standpoint. The introduction of water vapor into the atmosphere, in varying quantities is one of the chief means whereby thermal energy is communicated to the upper levels of the atmosphere. The economic importance of a generous supply of water vapor is self-evident.

It is, therefore not surprising that geographers and others from time to time, beginning with Sir John Murray's work in 1887, have sought to determine a balance between the income of water vapor as realized in the phenomenon of evaporation and the outgo in the form of rain, snow, sleet, hail, and dew.

It will be admitted that our knowledge of the amount of precipitation that occurs over the surface of the globe is quite incomplete; there is a distressing lack of information concerning oceanic precipitation. And if so little is known of the distribution of precipitation, still less is known of the amount and seasonal distribution of evaporation over the globe, especially from the water surfaces.

The basic material used in deducing the total precipitation of the globe is, of course, such charts of annual precipitation as may have been prepared and published, and naturally the accuracy of the annual totals of rainfall are directly proportional to the fidelity with which the charts represent the true precipitation of the globe.

In the case of evaporation the circumstances with respect to mapping the distribution of evaporation are such that no attempt as yet has been made to portray the annual amount of evaporation even approximately. The most recent useful contribution on the subject is that of Dr. George Wüst,[1] abstracted in MONTHLY WEATHER

REVIEW, **50**:313–14. Doctor Wüst accepts the values for precipitation, run-off and evaporation given by Fritzsche,[2] for the region between 60° N. lat. and 40° S. lat. and supplementing these by assigning values for the regions poleward he arrives at the conclusion that the annual evaporation from the land amounts to 75,000 cu. km. per year or 21,989 cu. km. less than Brückner's determination of an earlier date.

Practically all of the investigators have followed Murray in considering the total quantity of evaporation from land areas as the difference between the total rainfall thereon and the amount of water discharged by the rivers into the oceans.

Each investigator places the total precipitation over the entire earth as equal to the total evaporation. I introduce at this time a small comparative table from Wüst (loc. cit.) giving the results reached by the several students of the problem.

Different determinations of the hydrology of the earth

[Amounts in 1,000 km.^{3}/year]

	Precipitation			Evaporation		
	Fritzsche-Brückner	Schmidt-Fritzsche	Wüst-Fritzsche	Fritzsche-Brückner	Schmidt-Fritzsche	Wüst-Fritzsche
Ocean	353.4	242.4	267.1	384.0	273.0	304.2
Land	111.9	111.9	112.1	81.3	81.3	75.0
Earth	465.3	354.3	379.2	465.3	354.3	379.2

From the above table it may be seen that in general the results of the six investigators as paired by Wüst are mostly in fair agreement; in some cases, however, the disagreements are rather marked, for example, Fritzsche-Brückner estimate the total precipitation of the earth as 465,300 cu. km. while Schmidt-Fritzsche place it at 354,300 cu. km. or 111,000 cu. km. less. Wüst-Fritzsche estimate the total evaporation at 86,100 cu. km. less than Brückner and Fritzsche.

Doctor Wüst is of opinion based on the results of Bigelow's work that it is necessary to apply a reduction factor of 0.82 to Brückner's results making the total oceanic evaporation as given by him 79,800 cu. km. too great. Accepting this criticism the total oceanic evaporation quoted by Zon [3] from Brückner is about 19,000 cu. miles too great. (79,192 cu. km.)

The investigators subsequent to Murray followed his lead in neglecting the amount of water annually devoted to replenishing the water that is very deep in the earth's crust such as artesian flow and that derived from deep wells, 3,000 to 4,000 feet in depth. It is true, of course, that approximate equilibrium in the free water content of the earth's crust has been reached many ages ago; nevertheless it would seem on first thought that very considerable draughts on that supply are made annually and that these amounts must be replenished by rainfall.

Very few worth-while statistics of the draft that is made on the deep earth water supply are available, but using what few can be found, computation shows that the total amount when compared with the total rainfall of the globe may be neglected. At best the water so used is lumped with total evaporation and serves to make that quantity slightly larger than it should be.

I also question the accuracy of the item given by Brückner and quoted by Zon (loc. cit.), viz, "Amount of ocean vapor carried to the land (net)" on the ground that neither the amount of water vapor carried by the atmosphere where it impinges on the land nor the amount of air exchange between land and sea is or can be even approximately known. The best that can be said is that on the average of a number of years the amount of exchange of air is substantially the same.

The unfortunate thing about the statement above quoted and others of like character which occasionally come from persons of high standing in their chosen professions is that the lay reader frequently does not and can not distinguish between the sound and the unsound when matters concerning the physical properties of the atmosphere are concerned.

Another statement by Brückner which in the original is quite correct, but by the suppression of a modifying clause is erroneously interpreted, is the emphasis placed on the importance of land masses as furnishing a supply of water vapor that is later condensed and falls as rain or snow.

I quote a translation of his words and have italicized those most generally omitted in quotations.

> Not ineffective is the rôle which the land surface plays in the circulation; on a mighty scale it adds to the moisture content of the air; nearly two-thirds of the rain falling on land comes from the masses of vapor furnished by itself and is thus of continental origin. *To be sure, the ocean is the source of these masses of vapor;* it furnishes a certain amount of water which repeatedly changes position over the land, here rather rapidly, there more slowly, and thus enters many times into the phenomenon of precipitation. (Geographische Zeitschrift, Vol. VI, p. 96.)

In discussing this subject with my colleague, Dr. W. J. Humphreys, he reverted to the fact that some years ago, to be precise, in 1914, he had drawn up a concise statement of the relations between world evaporation, precipitation, and run-off. Doctor Humphreys has kindly consented to the publication of this statement. See the succeeding article.

[1] Die Verdunstung auf dem Meere. Veröff. d. Inst. f. Meerskunde, N. F. Reihe A Heft 6 1920 (S85).
[2] Niederschlag, Abfluss und Verdunstung an freien wasserflächen ein Beitrag zum Wärmehaushalt des Weltmeeres und zum wasser haushalt der Erde. Ann. d. Hydrog. usw. 1915.
[3] Zon, Raphael, Final Report National Waterways Commission, 1912. (Zon's article in this report was recently reprinted.)

SOME RELATIONS BETWEEN EVAPORATION, PRECIPITATION, AND RUN-OFF

By W. J. HUMPHREYS

Many efforts have been made to find important relations between evaporation, precipitation, and run-off, but while such relations can be found it nearly always happens that it is impossible to deduce from them the value of any one of the quantities in terms of measurable values of the others. The restricted range and application of these relations will be clear from the following:

(1) *For the world as a whole.*—Evaporation = Precipitation.

(2) *For all land areas jointly.*—

Let P_o = precipitation coming from ocean evaporation.
P_L = precipitation coming from land evaporation.
$P = P_o + P_L$ = total precipitation over land.
R_s = surface run-off.
R_u = underground run-off.
R = total run-off.
E = total land evaporation.

Then $P_o = R$; $P_L = P - R = E$.